Assisted colonization of an endangered chaparral shrub is confounded by exotic root-rotting *Phytophthora* species

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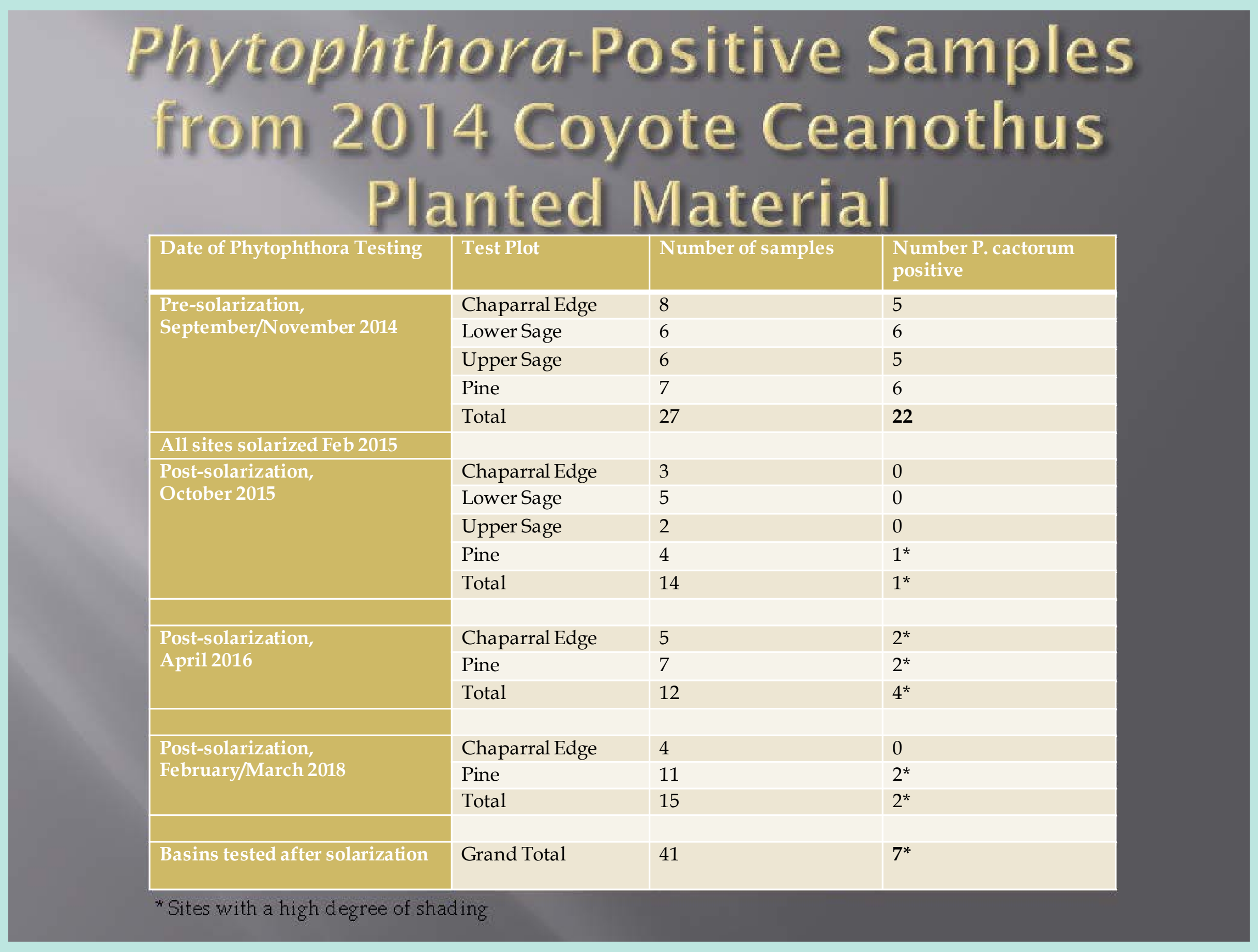
Introduction

The endangered Coyote Ceanothus (*Ceanothus ferrisiae*; CEFE), a serpentine chaparral endemic, is known from only three populations in Santa Clara County, CA. In order to mitigate impacts to the largest population of Coyote Ceanothus from a planned seismic retrofit of Anderson Dam, a new population must be created proactively. A potential mitigation site was selected in pristine habitat on Coyote Ridge, north of the reservoir (Fig. 1). In 2014 nursery stock of Coyote Ceaothus planted at the introduction site was discovered to be almost universally infected by *Phytophthora cactorum*, an exotic root-rotting pathogen. Planting basins were remediated via solarization using 2 layers of 6 mil clear thermal anti-condensate greenhouse film. Subsequent planting efforts at the site have utilized a combination of direct seeding and nursery-grown material, with all plant materials handled via strict phytosanitary procedures during the growing and installation process.



Phytophthora-Positive Samples from 2014 Coyote Ceanothus Planted Material

Date of Phytophthora Testing	Test Plot	Number of samples	Number P. cactorum positive
Pre-solarization, September/November 2014	Chaparral Edge	8	5
	Lower Sage	6	6
	Upper Sage	6	5
	Pine	7	6
	Total	27	**22**
All sites solarized Feb 2015			
Post-solarization, October 2015	Chaparral Edge	3	0
	Lower Sage	5	0
	Upper Sage	2	0
	Pine	4	1*
	Total	14	1*
Post-solarization, April 2016	Chaparral Edge	5	2*
	Pine	7	2*
	Total	12	4*
Post-solarization, February/March 2018	Chaparral Edge	4	0
	Pine	11	2*
	Total	15	2*
Basins tested after solarization	Grand Total	41	**7***

* Sites with a high degree of shading

Fig 2. Summary of results from 2014 planted Coyote Ceanothus container material in Coyote Ridge introduction site. Sampling from April 26 onward is concentrated in plots that have shaded planting basins.

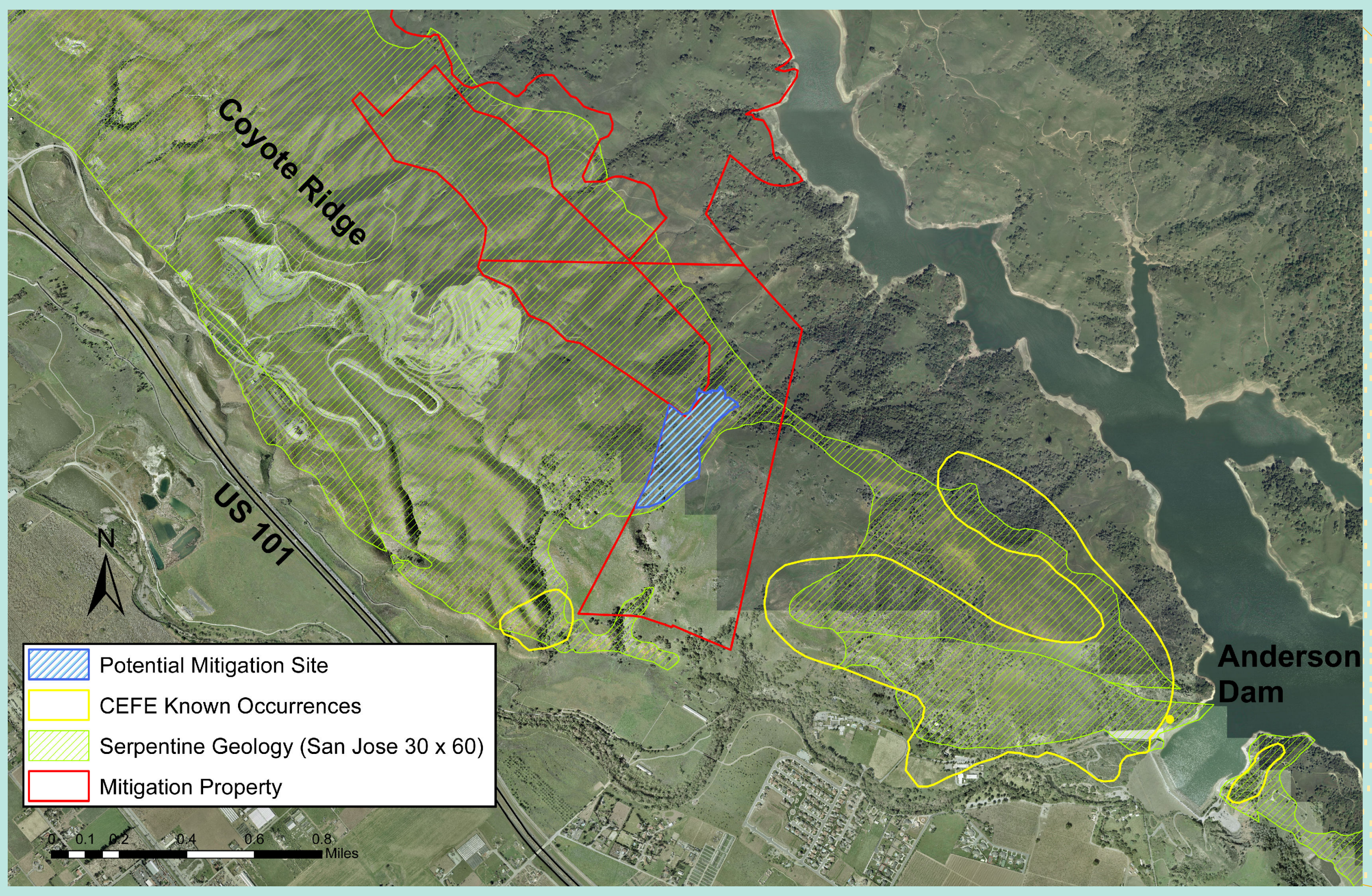
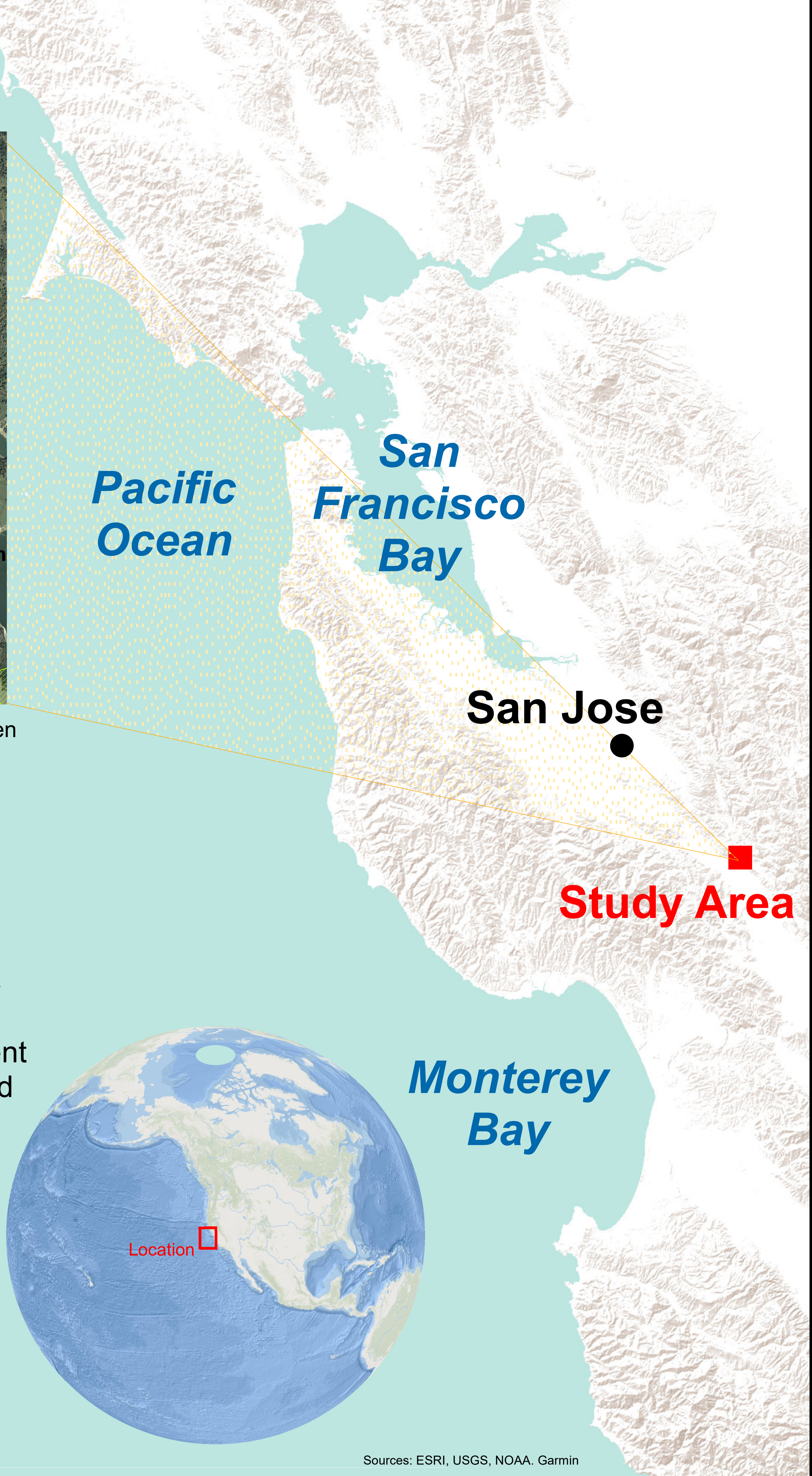


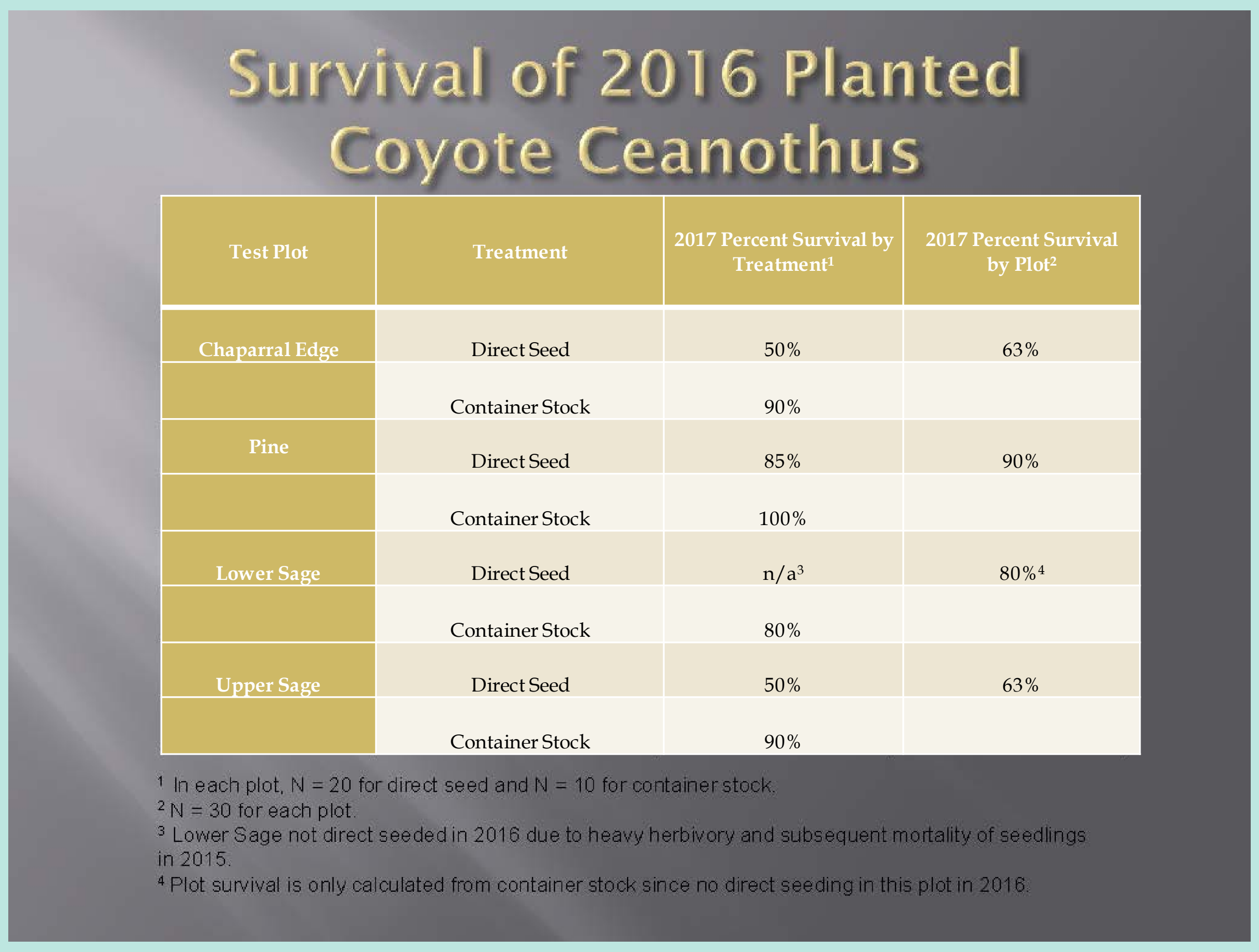
Fig 1. The potential mitigation site on Coyote Ridge, located 0.8 km equidistant between two of the three known populations of CEFE.



Sources: ESRI, USGS, NOAA, Garmin

Results

Solarization of infected basins was most effective in areas of full sun. Heavily-shaded basins remain infected (Fig. 2). Temperature monitoring indicated that *P. cactorum* persisted where soil temperatures at 20cm did not exceed 35 degrees C for at least 100 hours. Shaded basins are currently under evaluation for other treatment methods, including heat treatment of soil by other means. Monitoring results of survival/health and vigor of direct seeded and container-grown material one year after planting using phytosanitary BMPs indicate high survival rates and excellent health and vigor of container stock (Figs. 3 and 4). Higher mortality and initially lower health and vigor of seedlings is common with direct seeding efforts and we expect that the differences will be reduced over time with plant establishment. Direct seeding offers increased suitability to micro site conditions and reduces the risk of pathogen introduction.

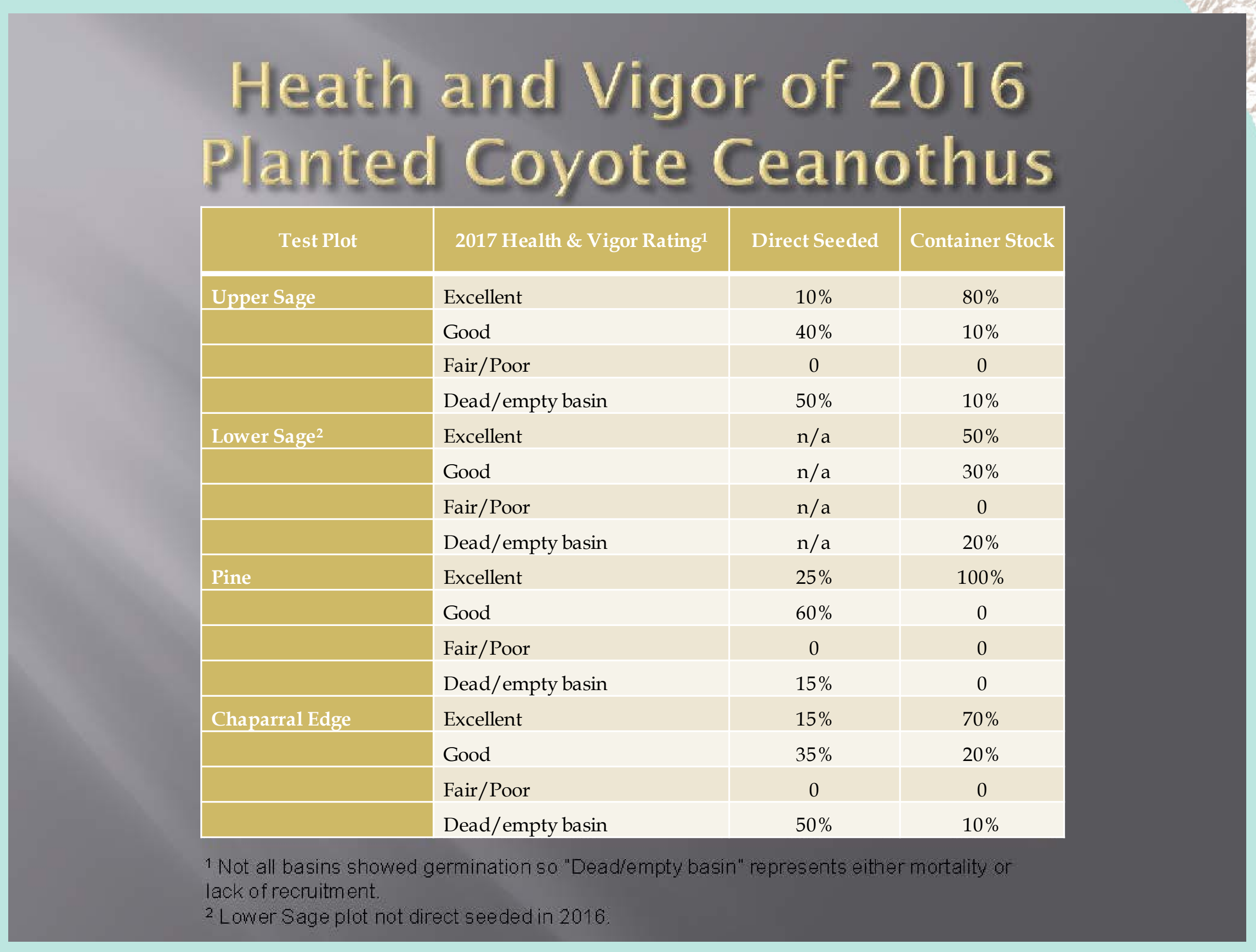


Survival of 2016 Planted Coyote Ceanothus

Test Plot	Treatment	2017 Percent Survival by Treatment[1]	2017 Percent Survival by Plot[2]
Chaparral Edge	Direct Seed	50%	63%
	Container Stock	90%	
Pine	Direct Seed	85%	90%
	Container Stock	100%	
Lower Sage	Direct Seed	n/a[3]	80%[4]
	Container Stock	80%	
Upper Sage	Direct Seed	50%	63%
	Container Stock	90%	

[1] In each plot, N = 20 for direct seed and N = 10 for container stock.
[2] N = 30 for each plot.
[3] Lower Sage not direct seeded in 2016 due to heavy herbivory and subsequent mortality of seedlings in 2015.
[4] Plot survival is only calculated from container stock since no direct seeding in this plot in 2016.

Fig 3. Percent survival by test plot and treatment for 2016 direct seeded and container stock of Coyote Ceanothus. Monitoring date October 3, 2017.

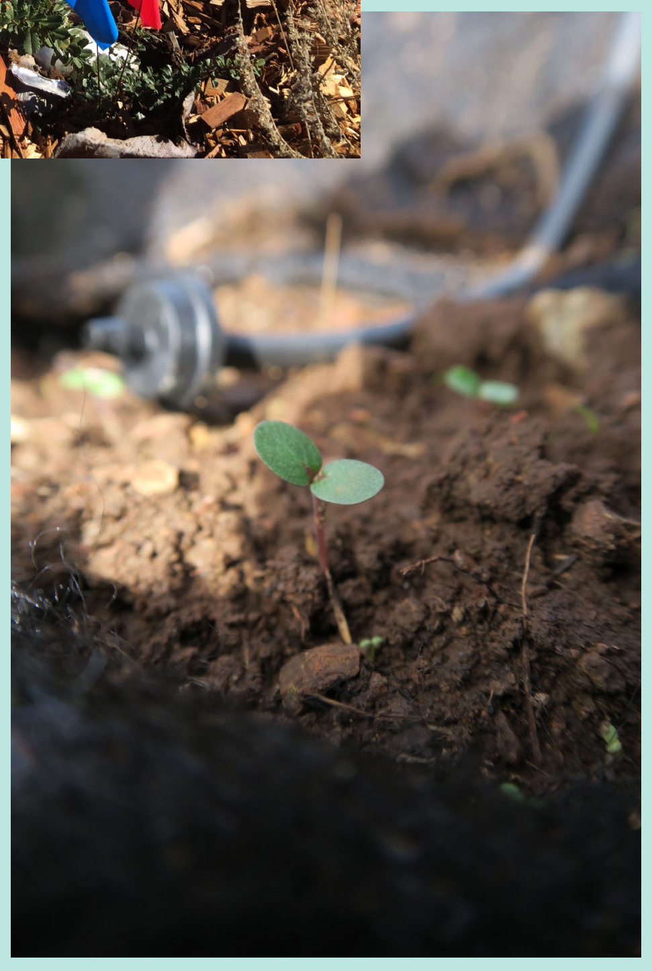


Heath and Vigor of 2016 Planted Coyote Ceanothus

Test Plot	2017 Health & Vigor Rating[1]	Direct Seeded	Container Stock
Upper Sage	Excellent	10%	80%
	Good	40%	10%
	Fair/Poor	0	0
	Dead/empty basin	50%	10%
Lower Sage[2]	Excellent	n/a	50%
	Good	n/a	30%
	Fair/Poor	n/a	0
	Dead/empty basin	n/a	20%
Pine	Excellent	25%	100%
	Good	60%	0
	Fair/Poor	0	0
	Dead/empty basin	15%	0
Chaparral Edge	Excellent	15%	70%
	Good	35%	20%
	Fair/Poor	0	0
	Dead/empty basin	50%	10%

[1] Not all basins showed germination so "Dead/empty basin" represents either mortality or lack of recruitment.
[2] Lower Sage plot not direct seeded in 2016.

Fig 4. Health and vigor by test plot and treatment of 2016 direct seeded and container stock of Coyote Ceanothus. Monitoring date October 3, 2017.



Conclusions

Growing and installing plants via phytosanitary methods has resulted in healthy and vigorous plants establishing at the introduction site so far. Project challenges include the remote location, maintaining strict sanitation practices for all materials introduced to the site, and the complexity of managing and monitoring multiple planting years. Conducting translocation and recovery activities in sensitive habitats with endangered species is complex, requiring new considerations in how such projects are designed and implemented.

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